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## Grass Carp Larvae in the Lower Missouri River and Its Tributaries

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**Abstract.**—We surveyed the lower Missouri River over its entire length in Missouri and 23 tributaries for larval grass carp *Ctenopharyngodon idella* in 1987 and 1988. Grass carp larvae appeared as early as 23 May and as late as 15 July in 1987. We captured larvae in four tributaries and at three Missouri River stations, all in central Missouri; densities ranged from 0.9 to 67.3 larvae/100 m<sup>3</sup>. Larvae ranged in total length from 6.1 to 7.9 mm, and there was no relationship between fish length and date of capture. Larval grass carp occurred at three stations, 8, 4, and 2 km from the mouth, on each of two intensively sampled tributaries, Moreau River and AuxVasse Creek. The greatest densities occurred at the most downstream station in each stream. Whether these larvae were produced in the Missouri River or in the tributaries is not certain; however, their presence at stations 8 km from the mouth in these tributaries suggests that grass carp may be capable of spawning in smaller streams than previously reported. Grass carp larvae were absent in 1988 samples, possibly due to reduced flows associated with a drought. The presence of grass carp larvae in the Missouri River and its tributaries suggests that the species reproduces at least in central Missouri and may become established in smaller river systems elsewhere in the Mississippi River basin.

The grass carp *Ctenopharyngodon idella* has been widespread in the lower Missouri River since 1974 (Pflieger 1978) and continues to increase in abundance. Commercial fishermen reported a record harvest of grass carp from the Missouri River in 1987 (8.2 tonnes), which constituted over 4% of the commercial harvest from the Missouri River (Robinson 1988). Nearly 87% of the state grass carp harvest is taken from the Missouri River and the remainder is from the upper Mississippi River.

Since Stanley (1976) predicted that grass carp could reproduce in rivers of the Mississippi Valley, several surveys have found larvae in the lower Mississippi River and some of its tributaries (Conner et al. 1980; Zimpfer et al. 1987). Pflieger (1978) suggested that the abundance of adult grass carp in the middle Mississippi River and its tributaries, particularly the Missouri River, was too large to result solely from escapement of adults from waters where grass carp were being reared and stocked. To date, the strongest evidence that grass carp reproduce in the Missouri River is the report of Pflieger and Grace (1987) that they found 78 dead juvenile grass carp (79–133 mm standard length) in a desiccated floodplain pool of the Missouri River near Easley, Missouri, in 1984. We document that grass carp reproduced in the lower Mis-

souri River and perhaps in at least four of its tributaries in Missouri, based on the presence of larvae.

### Study Area

We intensively sampled the Missouri River near the mouths of four tributaries and the lower 8 km of those tributaries (Table 1). The largest and most upstream tributary (Missouri River kilometer 327; distance from the river mouth) is the Lamine River. AuxVasse Creek, the smallest and most downstream of the four tributaries (Missouri River kilometer 195), has a higher gradient over its lower 50 km than the others (Table 1), but none of the tributaries has a measurable gradient in the lower 8 km studied. We also extensively sampled the Missouri River and the lower 2 km of 23 tributaries from the mouth of the Nishnabotna River in northwest Missouri to the confluence of the Missouri River with the upper Mississippi River (Table 2).

### Methods

We used a push-net system on a 4.9-m boat to sample ichthyoplankton. The system deployed two conical nets (0.5 m in diameter, and 2.0 m long with 0.8-mm mesh), one off each side of the bow. We positioned the nets just below the surface and pushed them downstream at about 1 m/s faster than the current. We preserved all material from the nets in 5% formalin. We also measured water temperature at about 0.3 m below the surface at each station.

For intensive surveys, we sampled the four trib-

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TABLE 1.—Summary of physical characteristics of intensively sampled Missouri River tributaries. Mean depth and mean width are from the lower 8 km and gradient is over the lower 50 km of the tributaries.

Tributary	Water-shed area (km <sup>2</sup> )	Mean depth (m)	Mean width (m)	Gradient (m/km)
Lamine River	6,838	3.7	62.2	0.06
Perche Creek	1,049	1.8	36.6	0.24
Moreau River	1,502	1.3	41.0	0.24
AuxVasse Creek	944	0.9	42.2	0.84

utaries and the Missouri River biweekly beginning in mid-March and continuing through July in 1987 and 1988. At each tributary, we took samples at each of three stations, 8, 4, and 2 km upstream from the tributary mouth, and at a Missouri River station 1 km upstream from the tributary mouth. Sampling alternated between the Lamine River and Perche Creek one week and the Moreau River and AuxVasse Creek the following week. We took two 5-min samples at midchannel at each of the tributary stations. Each sweep of two nets filtered about 110 m<sup>3</sup> of water. We took three 1-min samples (22 m<sup>3</sup> each) at the Missouri River stations, one in each of the right, middle, and left thirds of the river. We used a shorter sampling time in the Missouri River because the nets quickly filled with organic debris. We collected Missouri River samples at dusk for safety and took the tributary samples at night, usually between dusk and 0200 hours.

For extensive surveys, we took a series of one-time samples at stations in the Missouri River and other tributaries in May 1987 and 1988. In 1987, we sampled at three stations on the Missouri River from the mouth of the Grand River to the mouth of the Gasconade River, and at one station in each of 12 tributaries over this river reach (Table 2). All of the tributary stations were 2 km upstream from the tributary mouth, and we took all samples at night. In 1988, we sampled the Missouri River at 13 stations and 20 tributaries from the mouth of the Nishnabotna River in northwest Missouri to the confluence of the Missouri and upper Mississippi Rivers. As in 1987, tributary stations were 2 km upstream from the tributary mouth, but in 1988, we took all samples during daylight hours. In both years, we used 5-min sweeps in tributaries and 1-min sweeps in the Missouri River.

We sorted and identified larvae and transferred them to 70% isopropanol after ample time for fixation in formalin. We used Conner et al. (1980) as a guide to identify grass carp larvae. Darrel Snyder (Larval Fish Laboratory, Colorado State

TABLE 2.—Distribution of sampling stations for extensive survey of the lower Missouri River and its tributaries in May 1987 and 1988. Numbers in parentheses represent the number of stations at which grass carp larvae were captured.

River segment (km upstream from the Mississippi River)	Number of tributary stations		Number of Missouri River stations	
	1987	1988	1987	1988
0–150	0	4	0	2
151–300	12 (4)	10	5 (3)	7
301–450	4	4	2	2
451–600	0	3	0	2
601–750	0	2	0	2
751–900	0	2	0	2

University) verified the identity of representative specimens.

### Results and Discussion

We caught grass carp larvae in four tributaries and at three Missouri River stations in 1987 (Tables 2, 3). We captured larvae as early as 23 May and as late as 15 July; however, most of the larvae were taken within a 6-d period in late May. All larvae came from stations in central Missouri, between Moniteau Creek, Howard County (river kilometer 299), and the station at river kilometer 167 on the Missouri River. The total lengths (TL) of larvae captured were within a narrow range (6.1–7.9 mm) and did not vary with respect to date. Water temperatures at the time of capture ranged from 23 to 28°C.

We captured grass carp larvae at all three stations on the Moreau River and at the adjacent Missouri River station on 27 May 1987 (Table 3). We also found grass carp larvae at all three stations on AuxVasse Creek on 28 May 1987. On both tributaries, the greatest densities occurred at the most downstream station (2 km) and were an order of magnitude greater than at the more upstream stations. No grass carp larvae appeared in Lamine River or Perche Creek samples even though we sampled in both tributaries within 1 d of catching larvae at other stations.

Two mechanisms may account for the presence of grass carp larvae in the tributaries: (1) adults spawn upstream in the tributaries and currents carry the eggs and larvae to the quiet water at the tributary mouth, or (2) adults spawn in the Missouri River and larvae move into the lower ends of the tributaries. These mechanisms are not mutually exclusive.

Information on spawning and habitat require-



TABLE 3.—Summary of abundances and sizes of larval grass carp at sampling stations in the Missouri River and its tributaries in 1987. The distance from the tributary mouth to the Missouri-Mississippi river confluence is given in parentheses after each tributary name.

Date	Tributary or river	Station location (river km) <sup>a</sup>	Water temperature (°C)	Number of larvae captured	Density (Number of larvae/100 m <sup>3</sup> )	Size of larvae (total length, mm)	
						Range	Mean (SE)
23 May	Moniteau Creek (299 km)	2	24	3	1.3	6.6–7.6	7.3 (0.35)
23 May	Petite Saline Creek (286 km)	2	23	3	1.3	7.3–7.5	7.4 (0.06)
26 May	Missouri River	167	23	8	12.0	6.6–7.9	7.5 (0.13)
27 May	Missouri River	224	24	5	7.5	6.7–7.1	6.9 (0.07)
27 May	Moreau River (223 km)	8	26	4	1.8	7.0–7.6	7.4 (0.14)
27 May	Moreau River	4	26	2	0.9	7.5–7.7	7.6 (0.10)
27 May	Moreau River	2	26	38	17.0	6.1–7.8	7.1 (0.06)
28 May	AuxVasse Creek (194 km)	8	26	14	6.3	6.2–7.9	7.3 (0.14)
28 May	AuxVasse Creek	4	26	1	0.4	7.6	7.6
28 May	AuxVasse Creek	2	24	150	67.3	6.2–7.8	7.2 (0.03)
3 June	Missouri River	275	23	3	4.5	6.2–6.9	6.6 (0.22)
25 June	AuxVasse Creek	2	28	2	0.9	7.1–7.5	7.3 (0.20)
15 July	Missouri River	275	26	2	3.0	7.0–7.1	7.0 (0.05)

<sup>a</sup> Station locations are given as distances (km) from the mouth of the Missouri River or of the tributary.

ments for grass carp larvae (e.g., high current velocities and long segments of unimpounded river; Stanley et al. 1978) suggests that the tributaries in which we found grass carp larvae are not large enough to attract spawning adults or to retain larvae. It is possible that the larvae found at the 2-km stations on tributaries originated in the Missouri River and either swam upstream into the slow currents of the tributaries or were carried to these locations by reversed currents. At times, Missouri River discharge rose without an increase in local tributary discharge. When this occurred, Missouri River water spread into the tributaries and caused reversed currents as far as 2 km upstream from the tributary mouths. Although this may account for the great abundance of larvae at the 2-km stations on the tributaries, we have never seen the currents reversed as far as 8 km upstream. The Missouri River discharge had risen slightly and then declined in the 7 d preceding our capture of larvae in the Moreau River and AuxVasse Creek. As a result, the Moreau River and AuxVasse Creek were stagnant at the 2-km station and were flowing in a downstream direction at the 4- and 8-km stations on 27 and 28 May. If the larvae at the 8-km stations on these streams originated in the Missouri River, they almost certainly had to swim at least half of the distance from the river to the 8-km station without the aid of reversed currents and against downstream currents. Based on the descriptions by Shireman and Smith (1983), the larvae we captured (6.1–7.9 mm TL) ranged in age from 1 to 7 d posthatching and were unlikely to have swum this distance.

Stanley et al. (1978) reported that a minimum

velocity of 0.6 m/s is required for successful spawning by grass carp; however, more recent data show that lower current velocities (0.2–0.5 m/s) can be sufficient to suspend grass carp eggs (Leslie et al. 1982). Although the current was slow to nonexistent in the tributary reaches we sampled, upstream areas may provide sufficient current to stimulate spawning and to carry the developing eggs to the slow water near the mouths of the tributaries. Current velocity at upstream locations on the Moreau River (>50 km from the mouth) range from 0.2 to greater than 1.0 m/s during spring (Lohman 1988). Because the Moreau River is a lower-gradient stream than AuxVasse Creek, even greater current velocities may be available in the latter stream. We do not have information on the gradient or current velocities upstream from the Petite Saline or Moniteau creek sites; however, both streams are shorter and narrower than the Moreau River and AuxVasse Creek.

The absence of grass carp larvae from Perche Creek, the Lamine River, and other large tributaries sampled in the extensive study in 1987 is enigmatic. We captured the larvae of other riverine-spawning species (e.g., paddlefish *Polyodon spathula*, blue sucker *Cycleptus elongatus*, and freshwater drum *Aplodinotus grunniens*) in the Lamine River (Brown 1989). If grass carp larvae did occur in these tributaries, either our sampling schedule missed the apparently brief time at which larvae were vulnerable to capture or the greater discharges in the larger tributaries may have carried larvae into the Missouri River. Alternatively, grass carp larvae did not occur in these tributaries, either because some necessary spawning condi-



tions other than current velocity were lacking or conditions were not suitable for larvae to move into these tributaries from the Missouri River.

It is difficult to estimate the size of the spawning population based on the 1987 data; however, several considerations suggest that the adult density is low. The average daily discharge in the Missouri River at Boonville from 23 to 28 May 1987 was  $1.5 \times 10^8 \text{ m}^3$ . At the highest density of larvae measured in the Missouri River (12 larvae/100  $\text{m}^3$ ), the daily total number of grass carp larvae was  $1.6 \times 10^7$ , which could be produced by 30–60 adult females (Shireman and Smith 1983). In addition, densities of grass carp larvae in AuxVasse Creek were similar to those of goldeye *Hiodon alosoides* in 1987 (Brown 1989), and grass carp larvae appeared on the same dates as goldeye larvae. Because individual grass carp adults are 10–100 times as fecund as goldeyes (Scott and Crossman 1973), the larval densities suggest that the grass carp population has about 0.1 to 0.01 as many adults as the goldeye population. Pflieger and Grace (1987) reported that goldeyes constitute 1–2% of the assemblage of large fishes (species longer than 150 mm TL as adults) in the lower Missouri River.

We did not catch any grass carp larvae in 1988 even though we used a similar intensive-sampling protocol and an expanded extensive-sampling protocol. The mean daily discharge in the Missouri River was nearly twice as great in May 1987 as in 1988 and was less variable in 1988 (Brown 1989). Tributary discharges also were extremely low in 1988. The lower discharges in the tributaries and the Missouri River may have prohibited grass carp spawning or prevented the transport of eggs and larvae to the quiet water at the tributary mouths. The fact that we took only daytime samples in the 1988 extensive-sampling protocol may account for our failure to capture grass carp larvae if they were present in 1988. However, we took the samples from the intensively sampled streams at night in 1988 and did not capture any grass carp larvae in these. Furthermore, the high velocity and turbulence of the Missouri River make it unlikely that larvae could have avoided the surface waters at any hour in this habitat.

The long breeding season of grass carp (Conner et al. 1980; Zimpfer et al. 1987) was evident in our samples. We captured grass carp larvae with yolk sacs as late as 15 July 1987. The temperatures at which we found grass carp larvae (23–28°C) were similar to those at which Zimpfer et al. (1987) found the greatest densities in the Red River.

We captured only one grass carp longer than 7.9 mm TL, which may indicate a shift in the habits or habitats of young grass carp at greater sizes. The sampling gear we used is most effective at capturing small, pelagic fishes found near the water surface (e.g., larval gizzard shad *Dorosoma cepedianum* and goldeye; Brown 1989). It is much less effective for larvae that commonly occur near the stream bottom or bank, or for juveniles. Our failure to capture grass carp longer than 7.9 mm TL may be due to their greater swimming ability at larger sizes (Shireman and Smith 1983) or a shift in their habitat preference away from the surface water in midchannel (Stanley et al. 1978).

Factors such as predation, food supply, and availability of nursery areas probably affect the survival of grass carp larvae produced in the lower Missouri River basin. Many other streams along the lower Missouri River possess characteristics similar to those of Petite Saline Creek, Moniteau Creek, the Moreau River, and AuxVasse Creek, and these other tributaries may serve at least as nursery habitats and possibly as spawning sites for grass carp. Based on our results, it is clear that at least some adult grass carp captured by commercial fishermen in the lower Missouri River were wild fish produced in the Missouri River and perhaps in its tributaries.

These results make it clear that management biologists throughout the central Mississippi River basin can expect to face new challenges to fish habitats as wild grass carp populations grow and expand in distribution. Stanley et al. (1978) cited evidence from the Soviet Union that grass carp populations may cause changes in fish assemblages by depleting habitats with macrophytes. The effect of grass carp populations on riverine and floodplain habitats is likely to vary among watersheds. For example, the upper Mississippi River ecosystem is likely to experience greater effects than the Missouri River ecosystem because the upper Mississippi River remains connected with its floodplain, but the Missouri River is isolated from its floodplain. More information will be needed to effectively respond to the new challenges posed by wild populations of grass carp. Our data demonstrate that grass carp may be capable of spawning in smaller river systems and farther north than was previously documented in North America.

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